TITLE OF THE INVENTION

SEMICONDUCTOR DEVICE AND METHOD OF FABRICATING THE SAME

AND METHOD OF FORMING NITRIDE BASED SEMICONDUCTOR LAYER

5   BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a semiconductor device having a compound semiconductor layer composed of BN (boron nitride), GaN (gallium nitride), AlN (aluminum nitride) or

10 InN (indium nitride) or a group III-V nitride compound semiconductor (hereinafter referred to as a nitride based semiconductor) which is their mixed crystal and a method of fabricating the same, and a method of forming a nitride based semiconductor layer.

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Description of the Background Art

In recent years, a GaN based light emitting semiconductor device (a light emitting semiconductor device based on GaN) has been put to practical use as a light emitting

20 semiconductor device such as a light emitting diode which emits light in blue or violet or a semiconductor laser device. In fabricating the GaN based light emitting semiconductor device, there exists no substrate composed of GaN. Therefore, each layer is epitaxially grown on an insulating

25 substrate composed of sapphire (Al_2O_3) or the like.

Fig. 18 is a cross-sectional view showing the structure of a conventional GaN based light emitting diode. A light emitting diode shown in Fig. 18 is disclosed in Nikkei Micro Device, February, 1994, pp. 92 to 93.

5   In Fig. 18, a GaN buffer layer 62, an n-GaN layer 63, an n-AlGaN cladding layer 64, an InGaN active layer 65, a p-AlGaN cladding layer 66, and a p-GaN layer 67 are formed in this order on a sapphire substrate 61. A partial region from the p-GaN layer 67 to the n-GaN layer 63 is removed by

10   etching. A p electrode 68 is formed on the top surface of the p-GaN layer 67, and an n electrode 69 is formed on the exposed top surface of the n-GaN layer 63. Such a structure of the light emitting diode is referred to as a lateral structure.

15   The light emitting diode shown in Fig. 18 has a pn junction having a double hetero structure in which the InGaN active layer 65 is interposed between the n-AlGaN cladding layer 64 and the p-AlGaN cladding layer 66, and can emit light in blue.

20   In a conventional GaN based light emitting semiconductor device as shown in Fig. 18, however, dislocations of around $10^9/cm^2$ generally exist in a GaN based semiconductor crystal which is grown on a sapphire substrate depending on the difference in lattice constant between GaN

25   and the sapphire substrate. Such dislocations are propagated

from the surface of the sapphire substrate to a GaN based

semiconductor layer. In the light emitting semiconductor

device composed of the GaN based semiconductor layer on the

sapphire substrate, device characteristics and reliability

5   are degraded due to the dislocations.

As a method of solving the problem of the degradation

of the device characteristics and the reliability due to the

dislocations, epitaxial lateral overgrowth has been

proposed. The epitaxial lateral overgrowth is reported in

10   "Proceedings of The Second International Conference on

Nitride Semiconductors", October 27-31, 1997, Tokushima,

Japan, pp.444-446. Fig. 19 is a schematic sectional view

showing the steps for explaining the conventional epitaxial

lateral overgrowth.

15   As shown in Fig. 19 (a), an AlGaN buffer layer 82 is

grown on a sapphire substrate 81, and a GaN layer 83 is formed

on the AlGaN buffer layer 82. Dislocations 91 extending in

the vertical direction exist in the GaN layer 83. Striped

SiO$_2$ films 90 are formed on the GaN layer 83.

20   As shown in Fig. 19 (b), a GaN layer 84 is regrown on

the GaN layer 83 exposed between the striped SiO$_2$ films 90.

Also in this case, the dislocations 91 extend in the vertical

direction in the regrown GaN layer 84.

As shown in Fig. 19 (c), when the GaN layer 84 is further

25   grown, the GaN layer 84 is also grown in the lateral

direction. Accordingly, the GaN layer 84 is also formed on the SiO_2 films 90. No dislocations exist in the GaN layer 84 on the SiO_2 films 90.

As shown in Fig. 19 (d), when the GaN layer 84 is further grown, the GaN film 84 is formed on the SiO_2 films 90 and on the GaN layer 83 between the SiO_2 films 90.

When the epitaxial lateral overgrowth is used, a GaN crystal of high quality having no dislocations can be formed on the SiO_2 films 90.

In a region where the SiO_2 films 90 do not exist, however, the dislocations 91 from the underlying GaN layer 83 extend to the surface of the regrown GaN layer 84. Accordingly, the dislocations still exist on the surface of the GaN layer 84. When the light emitting semiconductor device is fabricated, therefore, a light emitting region must be limited to a region on the SiO_2 films. Therefore, it is impossible to increase the size of the light emitting region.

When the area of the SiO_2 film is increased in order to increase the area of the GaN layer of high quality, the surface of the GaN layer which is grown in the lateral direction cannot be flattened.

In the conventional GaN based light emitting diode shown in Fig. 18, the sapphire substrate 61 is an insulating substrate. Therefore, the n electrode 69 cannot be provided on the reverse surface of the sapphire substrate 61, and must

be provided on the exposed surface of the n-GaN layer 63.

Therefore, a current path between the p electrode 68 and the

n electrode 69 is longer, so that an operation voltage is

higher, as compared with those in a case where the n electrode

5   is provided on the reverse surface of a conductive substrate.

Furthermore, when a GaN based semiconductor laser

device is fabricated, it is difficult to form cavity facets

by a cleavage method as in a semiconductor laser device for

emitting red light or infrared light using a GaAs substrate.

10   Fig. 20 is a diagram showing the relationship between

the crystal orientations of a sapphire substrate and a GaN

based semiconductor layer. In Fig. 20, an arrow by a solid

line indicates the crystal orientation of the sapphire

substrate, and an arrow by a broken line indicates the crystal

15   orientation of the GaN based semiconductor layer.

As shown in Fig. 20, the a-axis and the b-axis of the

GaN based semiconductor layer formed on the sapphire

substrate are shifted 30° away from the a-axis and the b-

axis of the sapphire substrate.

20   Fig. 21 is a schematic perspective view of a

semiconductor laser device composed of a GaN based

semiconductor layer formed on a sapphire substrate.

In Fig. 21, a GaN based semiconductor layer 70 is formed

on a (0001) plane of a sapphire substrate 61. A striped

25   current injection region 71 is parallel to a <11$\bar{2}$0> direction

of the GaN based semiconductor layer 70. In this case, a {1

$\bar{1}$00} plane of the GaN based semiconductor layer 70 is inclined

at 30° to a {1$\bar{1}$00} plane of the sapphire substrate 61. Both

the sapphire substrate 61 and the GaN based semiconductor

5   layer 70 are easily cleaved along the {1$\bar{1}$00} plane.

The respective cleavage directions of the sapphire

substrate 61 and the GaN based semiconductor layer 70 thus

deviate. When a GaN based semiconductor laser device is

fabricated, therefore, it is difficult to form cavity facets

10 by a cleavage method, as in the semiconductor laser device

for emitting red light or infrared light which is formed on

the GaAs substrate. In this case, the necessity of forming

the cavity facets by etching is brought about. When the

cavity facets are formed by etching, however, it is

15 impossible to reduce an operation current of the

semiconductor laser device because it is difficult to form

facets perpendicular to the substrate.

On the other hand, various reports and proposals are

made with respect to methods of controlling a transverse mode

20 of the GaN based semiconductor laser device. Almost all of

the methods of controlling the transverse mode include two

types, i.e., a ridge waveguided structure and a self-aligned

structure which are employed by the conventional

semiconductor laser device for emitting red light or infrared

25 light.

Since the GaN based semiconductor layer is chemically stable, however, it cannot be patterned by wet etching, unlike an AlGaAs based semiconductor layer used for the conventional semiconductor laser device emitting red light

5 or infrared light, and must be patterned by dry etching such as RIE (Reactive Ion Etching) or RIBE (Reactive Ion Beam Etching).

In the GaN based semiconductor laser device, therefore, the patterning for fabricating the ridge waveguided

10 structure or the self-aligned structure cannot be performed easily and with good reproducibility. Moreover, device characteristics greatly vary depending on the precision of the dry etching.

15 SUMMARY OF THE INVENTION

An object of the present invention is to provide a nitride based semiconductor device (a semiconductor device based on a nitride) capable of performing a low-voltage operation.

20 Another object of the present invention is to provide a nitride based light emitting semiconductor device capable of performing a low-voltage operation and forming a facet by cleavage.

Still another object of the present invention is to

25 provide a method of fabricating a nitride based semiconductor

device in which the number of dislocations is reduced, a
low-voltage operation can be performed, and a facet can be
formed by cleavage.

   Still another object of the present invention is to
5 provide a method of forming a nitride based semiconductor
layer (a semiconductor layer based on a nitride) of high
quality having no dislocations in a wide region on a
substrate.

   Still another object of the present invention is to
10 provide a semiconductor device composed of a nitride based
semiconductor layer of high quality having no dislocations
in a wide region on a substrate.

   Still another object of the present invention is to
provide a light emitting semiconductor device having an
15 active layer of high quality having no dislocations in a wide
region on a substrate.

   Still another object of the present invention is to
provide a nitride based semiconductor device capable of
fabricating an active region of the device of high quality
20 without using etching.

   Still another object of the present invention is to
provide a refractive index guided nitride based light
emitting semiconductor device capable of forming an optical
waveguide path of high quality without using etching.

25   Still another object of the present invention is to

provide a method of fabricating a nitride based semiconductor
device capable of fabricating an active region of the device
of high quality without using etching.

A semiconductor device according to one aspect of the
5   present invention comprises a gallium arsenide substrate, a
first electrode layer formed on the gallium arsenide
substrate, a nitride based semiconductor layer formed on the
first electrode layer and containing at least one of boron,
gallium, aluminum and indium, and a second electrode layer
10   formed on the nitride based semiconductor layer.

In the semiconductor device, the first electrode layer
and the second electrode layer are respectively provided on
the bottom surface and the top surface of the nitride based
semiconductor layer on the gallium arsenide substrate.
15   Accordingly, a current path between the first electrode layer
and the second electrode layer is shortened. Consequently,
it is possible to reduce an operation voltage of the nitride
based semiconductor device.

The nitride based semiconductor layer may include an
20   active layer. In this case, the first electrode layer and
the second electrode layer are respectively provided on the
bottom surface and the top surface of the nitride based
semiconductor layer on the gallium arsenide substrate.
Accordingly, the current path between the first electrode
25   layer and the second electrode layer is shortened.

Consequently, it is possible to reduce the operation voltage
of the nitride based light emitting semiconductor device.

Particularly, it is preferable that the nitride based
semiconductor layer has a striped current injection region

5 for injecting a current into the active layer, the striped
current injection region is formed along a <1$\bar{1}$00> direction
of the nitride based semiconductor layer, the nitride based
semiconductor layer is arranged on the gallium arsenide
substrate such that the <1$\bar{1}$00> direction of the nitride based

10 semiconductor layer coincides with a <110> direction or a <1
$\bar{1}$0> direction of the gallium arsenide substrate, and a pair
of cavity facets is formed of a {110} plane or a {1$\bar{1}$0} plane
of the gallium arsenide substrate and a {1$\bar{1}$00} plane of the
nitride based semiconductor layer.

15 In this case, the cleavage direction of the nitride
based semiconductor layer and the cleavage direction of the
gallium arsenide substrate coincide with each other.
Accordingly, the cavity facets can be formed by the cleavage.
Therefore, a semiconductor laser device is realized as a

20 light emitting semiconductor device. Further, the
uniformity of device characteristics is improved, and the
reproducibility of the device characteristics is increased.

A method of fabricating a semiconductor device
according to another aspect of the present invention

25 comprises the steps of forming a first nitride based

semiconductor layer containing at least one of boron,

gallium, aluminum and indium on an insulating substrate,

forming an insulating film in a predetermined region on the

first nitride based semiconductor layer, forming a second

5 nitride based semiconductor layer containing at least one of

boron, gallium, aluminum and indium using epitaxial lateral

overgrowth on the first nitride based semiconductor layer and

the insulating film, removing the second nitride based

semiconductor layer except in a region on the insulating

10 film, joining the top surface of the second nitride based

semiconductor layer on the insulating film to one surface of

a gallium arsenide substrate through a first electrode layer,

removing the insulating film, to remove the insulating

substrate and the first nitride based semiconductor layer

15 from the second nitride based semiconductor layer, and

forming a second electrode layer on the second nitride based

semiconductor layer.

In the method of fabricating the semiconductor device,

the second nitride based semiconductor layer is formed using

20 the epitaxial lateral overgrowth on the insulating film on

the first nitride based semiconductor layer. Accordingly,

no dislocations are propagated to the second nitride based

semiconductor layer on the insulating film from the first

nitride based semiconductor layer. Consequently, a second

25 nitride based semiconductor layer of high quality having few

dislocations is obtained.

The first electrode layer and the second electrode layer are respectively provided on the bottom surface and the top surface of the second nitride based semiconductor layer on
5   the gallium arsenide substrate. Accordingly, a current path between the first electrode layer and the second electrode layer is shortened. Consequently, an operation voltage can be reduced.

Furthermore, when the top surface of the second nitride
10 based semiconductor layer is joined to one surface of the gallium arsenide substrate through the first electrode layer, the crystal orientations of the second nitride based semiconductor layer and the gallium arsenide substrate can be matched with each other. Accordingly, a facet of the
15 semiconductor device can be formed by cleavage. Consequently, the uniformity of device characteristics is improved, and the reproducibility of the device characteristics is increased.

Particularly, the step of forming the second nitride
20 based semiconductor layer may comprise the step of forming an active layer. Consequently, a light emitting semiconductor device is fabricated as the semiconductor device.

Furthermore, the step of forming the second nitride
25 based semiconductor layer may further comprise the step of

forming a striped current injection region for injecting a

current into the active layer along a <1Ī00> direction of the

second nitride based semiconductor layer, and the step of

joining the top surface of the second nitride based

5   semiconductor layer to one surface of the gallium arsenide

substrate through the first electrode layer may comprise the

step of matching the <1Ī00> direction of the second nitride

based semiconductor layer with a <110> direction or a <1Ī

0> direction of the gallium arsenide substrate.   The

10   fabricating method may further comprise the step of forming

a pair of cavity facets by cleavage along a {110} plane or

a {1Ī0} plane of the gallium arsenide substrate and a {1Ī

00} plane of the second nitride based semiconductor layer.

In this case, the cleavage direction of the nitride

15   based semiconductor layer and the cleavage direction of the

gallium arsenide substrate coincide with each other.

Accordingly, the cavity facets can be formed by the cleavage.

Consequently, a semiconductor laser device is realized as the

light emitting semiconductor device.   Further, the device

20   characteristics hardly vary, and the reproducibility of the

device characteristics is increased.

A method of forming a nitride based semiconductor layer

according to still another aspect of the present invention

comprises the steps of forming a first nitride based

25   semiconductor layer containing at least one of boron,

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gallium, aluminum and indium on an insulating substrate,
forming an irregular pattern including a recess having a
bottom surface formed of an insulator and a projection having
a top surface formed of an insulator in the surface of the
5   first nitride based semiconductor layer, and forming a second
nitride based semiconductor layer containing at least one of
boron, gallium, aluminum and indium on the insulators by
growth from the first nitride based semiconductor layer using
epitaxial lateral overgrowth.

10   In the method of forming the nitride based semiconductor
layer, the insulators are formed on the bottom surface of the
recess in the irregular pattern formed on the surface of the
first nitride based semiconductor layer and the top surface
of the projection in the irregular pattern. Accordingly, the
15   first nitride based semiconductor layer is exposed to only
side surfaces of the irregular pattern. Therefore, the
second nitride based semiconductor layer is formed on the
insulators by the growth in the lateral direction of the
nitride based semiconductor layer. Consequently, no
20   dislocations are propagated to the second nitride based
semiconductor layer from the first nitride based
semiconductor layer. As a result, a nitride based
semiconductor layer of high quality having no dislocations
is formed in a wide region on the substrate.   The step of
25   forming the irregular pattern may comprise the steps of

forming the irregular pattern such that the first nitride based semiconductor layer is exposed to the bottom surface of the recess, and forming an insulating film as the insulator on the bottom surface of the recess of the irregular pattern

5 and forming an insulating film as the insulator on the top surface of the projection of the irregular pattern.

Alternatively, the step of forming the irregular pattern may comprise the step of forming an insulating film as the insulator in a region on the first nitride based

10 semiconductor layer where the projection of the irregular pattern is to be formed and removing the first nitride based semiconductor such that the insulating substrate is exposed as the insulator except in a region on the insulating film.

Particularly, it is preferable that the irregular

15 pattern has a striped recess and a striped projection which extend along a <11$\bar{2}$0> direction of the first nitride based semiconductor layer. Consequently, the nitride based semiconductor layer is easily grown in the lateral direction.

It is preferable that a cross-sectional shape of the

20 projection of the irregular pattern is a rectangular shape or a reversed mesa shape having vertical side surfaces. When the insulating films are deposited on the irregular pattern, therefore, the insulating films can be formed only on the bottom surface of the recess in the irregular pattern and the

25 top surface of the projection in the irregular pattern.

Therefore, it is possible to omit the step of removing the
insulating films on the side surfaces of the irregular
pattern.

A semiconductor device according to still another
5 aspect of the present invention comprises an insulating
substrate, a first nitride based semiconductor layer formed
on the insulating substrate and containing at least one of
boron, gallium, aluminum and indium, an irregular pattern
being formed in the surface of the first nitride based
10 semiconductor layer, insulating films respectively formed on
the bottom surface of a recess and the top surface of a
projection of the irregular pattern of the first nitride
based semiconductor layer, and a second nitride based
semiconductor layer formed on the insulating films and
15 containing at least one of boron, gallium, aluminum and
indium.

In the semiconductor device, the insulating films are
respectively formed on the bottom surface of the recess in
the irregular pattern on the surface of the first nitride
20 based semiconductor layer and the top surface of the
projection in the irregular pattern, and the second nitride
based semiconductor layer is formed on the insulating films.
Accordingly, no dislocations are propagated to the second
nitride based semiconductor layer from the first nitride
25 based semiconductor layer. Consequently, a nitride based

semiconductor device of high quality having no dislocations
is realized in a wide region on the substrate.

The second nitride based semiconductor layer may
include an active layer. In this case, the insulating films

5   are respectively formed on the bottom surface of the recess
in the irregular pattern on the surface of the first nitride
based semiconductor layer and the top surface of the
projection in the irregular pattern, and the second nitride
based semiconductor layer is formed on the insulating films.

10 Accordingly, no dislocations are propagated to the second
nitride based semiconductor layer from the first nitride
based semiconductor layer. Consequently, a nitride based
semiconductor device including an active layer of high
quality having no dislocations is realized in the wide region

15 on the substrate.

A semiconductor device according to still another
aspect of the present invention comprises an insulating
substrate, a first nitride based semiconductor layer formed
on the insulating substrate and containing at least one of

20 boron, gallium, aluminum and indium, a plurality of striped
insulating films formed a predetermined distance away from
each other on the first nitride based semiconductor layer,
and a second nitride based semiconductor layer formed on the
first nitride based semiconductor layer and the plurality of

25 striped insulating films and containing at least one of

boron, gallium, aluminum and indium. The second nitride based semiconductor layer includes an active region of the device above the plurality of striped insulating films. The active region is an actually operating region other than an

5   electrode forming region of the semiconductor device.

In the semiconductor device, the second nitride based semiconductor layer is formed on the first nitride based semiconductor layer through the plurality of striped insulating films. Accordingly, few dislocations exist in the

10   second nitride based semiconductor layer on a region where the plurality of striped insulating films exist. Consequently, the active region of the device above the plurality of striped insulating films is increased in quality.

15   On the region where the plurality of striped insulating films exist, the growth rate of the second nitride based semiconductor layer is lower, as compared with that on the region where the plurality of striped insulating films do not exist. Consequently, the second nitride based semiconductor

20   layer on the region where the plurality of striped insulating films exist is concavely formed. Consequently, it is possible to fabricate the active region of the device without using etching.

The active region may include a light emitting portion.

25   In this case, the second nitride based semiconductor layer

is formed on the first nitride based semiconductor layer through the plurality of striped insulating films. Accordingly, few dislocations exist in the second nitride based semiconductor layer on the region where the plurality

5 of striped insulating films exist. Consequently, the light emitting portion above the plurality of striped insulating films is increased in quality.

On the region where the plurality of striped insulating films exist, the growth rate of the second nitride based

10 semiconductor layer is lower, as compared with that on the region where the plurality of striped insulating films do not exist. Consequently, the second nitride based semiconductor layer on the region where the plurality of striped insulating films exist is concavely formed. Consequently, it is

15 possible to fabricate a refractive index guided optical waveguide path without using etching.

Particularly, the second nitride based semiconductor layer may have a striped current injection region for injecting a current into the light emitting portion, and the

20 second nitride based semiconductor layer may comprise a pair of cavity facets perpendicular to the striped current injection region. Consequently, the current is injected in a stripe shape into the light emitting portion, thereby making lasing possible.

25 It is preferable that the plurality of striped

insulating films are formed along a $\langle 11\bar{2}0 \rangle$ direction of the first nitride based semiconductor layer. Consequently, the nitride based semiconductor layer is easily grown in the lateral direction, and the second nitride based

5   semiconductor layer is made higher in quality.

A method of fabricating a semiconductor device according to still another aspect of the present invention comprises the steps of forming a first nitride based semiconductor layer containing at least one of boron,

10 gallium, aluminum and indium on an insulating substrate, forming a plurality of striped insulating films a predetermined distance away from each other on the first nitride based semiconductor layer, and forming a second nitride based semiconductor layer containing at least one of

15 boron, gallium, aluminum and indium using epitaxial lateral overgrowth on the first nitride based semiconductor layer and the plurality of striped insulating films, to form an active region of the device above the plurality of striped insulating films. The active region is an actually operating

20 region other than an electrode forming region of the semiconductor device.

In the method of fabricating the semiconductor device, the second nitride based semiconductor layer is formed using epitaxial lateral overgrowth through the plurality of

25 striped insulating films on the first nitride based

semiconductor layer. Accordingly, few dislocations exist in the second nitride based semiconductor layer on the region where the plurality of striped insulating films exist. Consequently, the active region of the device above the

5 plurality of striped insulating films is increased in quality.

On the region where the plurality of striped insulating films exist, the growth rate of the second nitride based semiconductor layer is lower, as compared with that on the

10 region where the plurality of striped insulating films do not exist. Consequently, the second nitride based semiconductor layer on the region where the plurality of striped insulating films exist is concavely formed. Consequently, it is possible to fabricate an active layer of the device without

15 using etching.

A method of forming a nitride based semiconductor layer according to still another aspect of the present invention comprises the steps of forming a first nitride based semiconductor layer containing at least one of boron,

20 gallium, aluminum and indium on an insulating substrate, forming an irregular pattern having exposed side surfaces in the first nitride based semiconductor layer, and forming a second nitride based semiconductor layer containing at least one of boron, gallium, aluminum and indium on the irregular

25 pattern by growth from the exposed side surfaces of the

irregular pattern on the first nitride based semiconductor

layer using epitaxial lateral overgrowth.

In the method of forming the nitride based semiconductor

layer, the side surfaces of the irregular pattern formed in

5   the first nitride based semiconductor layer are exposed.

Therefore, the second nitride based semiconductor layer is

formed on the irregular pattern by growth in the lateral

direction of the nitride based semiconductor layer from the

exposed side surfaces. Consequently, no dislocations are

10   propagated to the second nitride based semiconductor layer

from the first nitride based semiconductor layer. As a

result, a nitride based semiconductor layer of high quality

having no dislocations is formed in a wide region on the

substrate.

15   The step of forming the irregular pattern may comprise

the steps of forming the irregular pattern such that the first

nitride based semiconductor layer is exposed to the bottom

surface of a recess, and forming insulating films on the

bottom surface of the recess of the irregular pattern and the

20   top surface of the projection of the irregular pattern.

Alternatively, the step of forming the irregular

pattern may comprise the step of forming an insulating film

in a region on the first nitride based semiconductor layer

where the projection in the irregular pattern is to be formed,

25   and removing the first nitride based semiconductor such that

the insulating substrate is exposed except in a region on the insulating film.

The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunciton with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic sectional view showing the steps of a method of fabricating a semiconductor laser device in a first embodiment of the present invention;

Fig. 2 is a schematic sectional view showing the steps of the method of fabricating the semiconductor laser device in the first embodiment of the present invention;

Fig. 3 is a schematic sectional view showing the steps of the method of fabricating the semiconductor laser device in the first embodiment of the present invention;

Fig. 4 is a schematic sectional view showing the steps of the method of fabricating the semiconductor laser device in the first embodiment of the present invention;

Fig. 5 is a schematic sectional view showing the steps of the method of fabricating the semiconductor laser device in the first embodiment of the present invention;

Fig. 6 is a schematic sectional view showing the steps

of the method of fabricating the semiconductor laser device

in the first embodiment of the present invention;

Fig. 7 is a diagram showing an energy band structure

of an MQW active layer in the semiconductor laser device shown

5   in Figs. 1 to 6;

Fig. 8 is a perspective view showing the relationship

between the crystal orientations of a sapphire substrate and

a GaN based semiconductor layer in the semiconductor laser

device shown in Figs. 1 to 6;

10   Fig. 9 is a schematic sectional view showing the steps

of a method of forming a GaN based semiconductor layer in a

second embodiment of the present invention;

Fig. 10 is a schematic sectional view showing the steps

of the method of forming the GaN based semiconductor layer

15   in the second embodiment of the present invention;

Fig. 11 is a schematic sectional view showing an

irregular pattern in a reversed mesa shape formed on the

surface of a GaN layer;

Fig. 12 is a schematic sectional view showing a method

20   of forming the irregular pattern in a reversed mesa shape on

the surface of the GaN layer;

Fig. 13 is a schematic sectional view showing an example

of a semiconductor laser device fabricated on the GaN layer

formed by the method shown in Figs. 9 and 10;

25   Fig. 14 is a schematic sectional view showing the steps

in another example of a method of forming a GaN based

semiconductor layer;

Fig. 15 is a schematic sectional view showing the steps

in another example of the method of forming the GaN based

5   semiconductor layer;

Fig. 16 is a schematic sectional view showing the steps

of a method of fabricating a semiconductor laser device in

a third embodiment of the present invention;

Fig. 17 is a schematic sectional view showing the steps

10   of the method of fabricating the semiconductor laser device

in the third embodiment of the present invention;

Fig. 18 is a schematic sectional view of a conventional

GaN based light emitting diode;

Fig. 19 is a schematic sectional view showing the steps

15   of a conventional method of forming a GaN based semiconductor

layer using epitaxial lateral overgrowth;

Fig. 20 is a diagram showing the relationship between

the crystal orientations of a sapphire substrate and a GaN

based semiconductor layer formed thereon; and

20   Fig. 21 is a diagram showing the relationship between

the crystal orientations of the sapphire substrate and the

GaN based semiconductor layer formed thereon.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

25   Figs. 1 to 6 are schematic sectional views showing the

steps of a method of fabricating a semiconductor laser device in a first embodiment of the present invention.

As shown in Fig. 1, an AlGaN buffer layer 2 is first formed on a sapphire substrate 1, and an undoped GaN layer 3 is grown on the AlGaN buffer layer 2. An SiO_2 film 4 having a predetermined width is formed on the GaN layer 3, and an n-GaN layer 5 is then grown on the GaN layer 3 and the SiO_2 film 4 using epitaxial lateral overgrowth.

An n-$In_PGa_{1-P}N$ (P = 0.1) crack preventing layer 6 having a thickness of 0.1 μm, an n-$Al_YGa_{1-Y}N$ (Y = 0.07) cladding layer 7 having a thickness of 1.0 μm, a multi quantum well active layer (hereinafter referred to as an MQW active layer) 8 described later, a p-$Al_YGa_{1-Y}N$ (Y = 0.07) cladding layer 9 having a thickness of 0.15 μm, and an n-$Al_ZGa_{1-Z}N$ (Z = 0.12) current blocking layer 10 having a thickness of 0.20 μm are then formed in this order on the n-GaN layer 5.

Fig. 7 is a diagram showing an energy band structure of the MQW active layer 8. As shown in Fig. 7, the MQW active layer 8 includes a multi quantum well structure obtained by alternately laminating six $In_XGa_{1-X}N$ (X = 0.03) quantum barrier layers 81 having a thickness of 60 Å and five $In_XGa_{1-X}N$ (X = 0.10) quantum well layers 82 having a thickness of 30 Å. Both surfaces of the multi quantum well structure are interposed between GaN optical guide layers 83 having a thickness of 0.1 μm.

A striped region having a width W0 at the center of the
n-Al$_z$Ga$_{1-z}$N current blocking layer 10 is then removed by
etching. In this case, the striped region between the n-
Al$_z$Ga$_{1-z}$N current blocking layers 10 is a current injection

5 region 19. The width W0 of the current injection region 19
is 2 μm, for example. The current injection region 19 is
formed in a <11$\bar{2}$0> direction of GaN.

Furthermore, a p-Al$_Y$Ga$_{1-Y}$N (Y = 0.07) cladding layer 11
having a thickness of 0.4 μm and a p-GaN contact layer 12

10 having a thickness of 0.1 μm are formed in this order on the
n-Al$_z$Ga$_{1-z}$N current blocking layer 10 and the p-Al$_Y$Ga$_{1-Y}$N
cladding layer 9.

Si is used as an n-type dopant, and Mg is used as a p-type
dopant. Examples of a method of growing each layer include

15 MOCVD (Metal Organic Chemical Vapor Deposition) or HVPE
(Hydride Vapor Phase Epitaxy).

In this case, dislocations extend in the vertical
direction from the GaN layer 3 to the p-GaN contact layer 12
in a region where the SiO$_2$ film 4 does not exist. No

20 dislocations exist from the n-GaN layer 5 to the p-GaN contact
layer 12 on the SiO$_2$ film 4.

As shown in Fig. 2, the region, from the p-GaN contact
layer 12 to the n-GaN layer 5, where the SiO$_2$ film 4 does not
exist are removed by dry etching such as RIE or RIBE.

25 Consequently, a GaN based semiconductor layer 18 having no

dislocations remains on the GaN layer 3.

Furthermore, in order to activate the p-type dopant, a p electrode 13 composed of Ni having a thickness of 5000 Å, Pt having a thickness of 100 Å, and Au having a thickness

5 of 1 μm is formed on the p-GaN contact layer 12, as shown in Fig. 3, after annealing at a temperature over 600 °C, for example, at 800 °C for 30 minutes.

As shown in Fig. 4, an n-GaAs substrate 14 of 100 μm thickness having ohmic electrodes 15a and 15b formed on its

10 top and reverse surfaces of (001) planes is prepared. The top surface of the p electrode 13 formed on the GaN based semiconductor layer 18 on the sapphire substrate 1 is joined by thermocompression (bonding) or fusion to the ohmic electrode 15a on the n-GaAs substrate 14.

15 When the thermocompression is used, it is desirable that the surface of the p electrode 13 and the surface of the ohmic electrode 15a are covered with Au in a state immediately after evaporation. When the fusion is used, it is desirable that an Au-Sn film having a thickness of approximately 3 μm is

20 formed on the n-GaAs substrate 14.

In joining the p electrode 13 and the ohmic electrode 15a, the respective crystal orientations of the GaAs substrate 14 and the GaN based semiconductor layer 18 are matched with each other such that the n-GaAs substrate 14 and

25 the GaN based semiconductor layer 18 have a relationship

shown in Fig. 8.

In Fig. 8, the GaN based semiconductor layer 18 is formed on a (001) plane of the n-GaAs substrate 14. A striped current injection region 19 corresponds to a region between the

5   n-$Al_zGa_{1-z}N$ current blocking layers 10 shown in Fig. 4, and a light emitting portion 20 is formed in the current injection region 19. The current injection region 19 is provided in a <1$\bar{1}$00> direction. In this case, the GaN based semiconductor layer 18 is joined to the n-GaAs substrate 14 such that the

10   current injection region 19 in the GaN based semiconductor layer 18 is parallel to a <110> direction or a <1$\bar{1}$0> direction of the n-GaAs substrate 14.

The sapphire substrate 1 and the n-GaAs substrate 14 shown in Fig. 4 are then dipped in a raw hydrofluoric acid,

15   to remove the SiO_2 film 4. The sapphire substrate 1 and the AlGaN buffer layer 2 and the GaN layer 3, having the dislocations, on the sapphire substrate 1 are removed from the GaN based semiconductor layer 18 on the n-GaAs substrate 14 by lift-off. Consequently, the GaN based semiconductor

20   layer 18 having no dislocations remains on the n-GaAs substrate 14, as shown in Fig. 5. In this case, it is desirable that a raw hydrofluoric acid containing a surface active agent is used such that side etching of the SiO_2 film 4 easily progresses.

25   Finally, as shown in Fig. 6a, an SiO_2 film 16 for

preventing short is formed on the top surface and side surfaces of the GaN based semiconductor layer 18 and the surface of the ohmic electrode 15a except in a region at the center of the n-GaN layer 5, and an n electrode 17 composed

5   of Ti having a thickness of 100 Å and Al having a thickness of 2000 Å is formed on the n-GaN layer 5 and the SiO$_2$ film 16.

Thereafter, a pair of cavity facets is formed by a cleavage method. In this case, a {1$\bar{1}$00} plane of the GaN based

10   semiconductor layer 18 and a {110} plane or a {1$\bar{1}$0} plane of the n-GaAs substrate 14 are cleavage planes, as shown in Fig. 8.

In the semiconductor laser device according to the present embodiment, the p electrode 13 and the n electrode

15   17 are respectively formed on the reverse surface and the surface of the GaN based semiconductor layer 18. Accordingly, a current path between the p electrode 13 and the n electrode 17 is shortened. Further, few dislocations exist in the GaN based semiconductor layer 18. Consequently,

20   a low-voltage operation and a low-current operation are possible.

The cleavage direction of the GaN based semiconductor layer 18 and the cleavage direction of the n-GaAs substrate 14 can be matched with each other. Accordingly, the cavity

25   facets can be easily formed by the cleavage method.

Although in the present embodiment, description was made of a case where the present invention is applied to the semiconductor laser device, the present invention is also applicable to light emitting semiconductor devices such as

5   a light emitting diode and the other semiconductor devices.

Figs. 9 and 10 are schematic sectional views showing the steps of a method of forming a GaN based semiconductor layer in a second embodiment of the present invention.

The top surface of a sapphire substrate 21 shown in Fig.

10   9 (a) has a (0001) plane (c face). As shown in Fig. 9 (b), an AlGaN buffer layer 22 and an updoped GaN layer 23 are grown in this order on the (0001) plane of the sapphire substrate 21. Dislocations 37 extending in the vertical direction exist in the GaN layer 23.

15   As shown in Fig. 9 (c), the GaN layer 23 is then etched by RIE using striped masks 29 composed of Ni, to form a striped irregular pattern on the surface of the GaN layer 23. The respective widths D of a recess and a projection in the irregular pattern shall be 5 μm, for example.

20   After the striped masks 29 are removed, an SiO_2 film 30 is then formed on the GaN layer 23, as shown in Fig. 9 (d).

As shown in Fig. 10 (e), the SiO_2 film 30 formed on side surfaces of the irregular pattern on the GaN layer 23 is then removed by etching.

25   Thereafter, as shown in Fig. 10 (f), a GaN layer 24 is

regrown. At this time, the underlying GaN layer 23 is exposed only to the side surfaces of the irregular pattern. When the regrowth of the GaN layer 24 is started, therefore, the GaN layer 24 is not grown in the vertical direction and is grown

5   only in the lateral direction. The dislocations 37 in the underlying GaN layer 23 are not propagated to the GaN layer 24 which is grown in the lateral direction on the SiO$_2$ films 30.

As shown in Fig. 10 (g), as the GaN layer 24 is regrown,
10 the SiO$_2$ films 30 on the lower step of the irregular pattern are filled in with the GaN layer 24. The GaN layer 24 is grown in the vertical direction.

Thereafter, as shown in Fig. 10 (h), the GaN layer 24 is grown in the lateral direction as well as the vertical
15 direction on the SiO$_2$ films 30 on the upper step of the irregular pattern. Accordingly, the surface of the GaN layer 24 is flattened. Consequently, the GaN layer 24 of high quality having no dislocations is formed on the SiO$_2$ films 30 on the irregular pattern.

20 In order to flatten the surface of the GaN layer 24 which is regrown, the GaN layer 24 must have a certain degree of thickness. The thickness required to flatten the surface of the GaN layer 24 differs depending on the growth conditions such as the width of the irregular pattern on the underlying
25 GaN layer 23 and the substrate temperature at the time of the

growth of the GaN layer 24. For example, when the respective widths of the recess and the projection in the irregular pattern are approximately 5 μm, the thickness of the GaN layer 24 must be approximately 10 to 20 μm.

5   GaN is easily grown in a <1$\bar{1}$00> direction. In order that the GaN layer 24 is easily grown in the lateral direction in the steps shown in Figs. 10 (f), 10 (g), and 10 (h), therefore, it is desirable that the striped masks 29 composed of Ni are formed in a <11$\bar{2}$0> direction perpendicular to the
10   <1$\bar{1}$00> direction of the GaN layer 23 in the step shown in Fig. 9 (c).

In order that the surface of the GaN layer 24 which is regrown in the step shown in Fig. 10 (h) is easily flattened, the mask width of the striped masks 29 composed of Ni and the
15   window width of the striped masks 29 (the width of a region where no Ni exists) which are used in the step shown in Fig. 9 (c) are preferably as small as not more than 10 μm, and more preferably 1 to 5 μm.

Furthermore, it is preferable that a cross-sectional
20   shape of the projection in the irregular pattern on the underlying GaN layer 23 is a rectangular shape or a reversed mesa shape (reversed trapezoidal shape) having vertical side surfaces rather than a mesa shape (trapezoidal shape).

As shown in Fig. 11, the cross sectional shape of the
25   irregular pattern on the GaN layer 23 is a reversed mesa

shape, and the SiO$_2$ films 30 are formed on the GaN layer 23

by a deposition method, such as electron beam evaporation,

inferior in step coverage, thereby making it possible to

prevent the SiO$_2$ films 30 from being deposited on the side

5   surfaces of the irregular pattern. Consequently, it is

possible to omit the step of removing the SiO$_2$ films 30 on

the side surfaces of the irregular pattern by etching.

Figs. 12 (a) and 12 (b) are schematic sectional views

showing a method of forming the irregular pattern in a

10   reversed mesa shape on the surface of the underlying GaN layer

23.

As shown in Fig. 12 (a), the striped masks 29 composed

of Ni are formed on the GaN layer 23, and the sapphire

substrate 21 is then inclined and is mounted on an etching

15   apparatus at the time of dry etching. In this state, the GaN

layer 23 is etched by dry etching such as RIE.

As shown in Fig. 12 (b), the sapphire substrate 21 is

inclined in the reverse direction. In this state, the GaN

layer 23 is etched by dry etching such as RIE. The irregular

20   pattern in the reversed mesa shape can be thus formed on the

surface of the GaN layer 23.

According to the method of fabricating the GaN based

semiconductor layer in the present embodiment, it is possible

to grow, even if the sapphire substrate 21 which differs in

25   lattice constant from GaN, the GaN layer 24 of high quality

having no dislocations on the entire surface of the sapphire substrate 21.

When a light emitting semiconductor device such as a light emitting diode or a semiconductor laser device composed of a GaN based semiconductor layer is fabricated on the GaN layer 24, it is possible to improve light output power-current characteristic and reliability.

Although in the example shown in Figs. 9 and 10, the sapphire substrate 21 is used as an insulating substrate, the sapphire substrate 21 can be also replaced with another insulating substrate such as an SiC substrate or a spinel $(MgAl_2O_4)$ substrate.

Fig. 13 is a schematic sectional view showing an example of a semiconductor laser device fabricated on the GaN layer formed by the method shown in Figs. 9 and 10.

In Fig. 13, an n-GaN layer 25, an n-InGaN crack preventing layer 26, an n-AlGaN cladding layer 27, an MQW active layer 28, and a p-AlGaN cladding layer 29 are formed in this order on a GaN layer 24 formed by the method shown in Figs. 9 and 10. An n-AlGaN current blocking layer 31 is formed except in striped regions on the p-AlGaN cladding layer 29. A p-AlGaN cladding layer 32 and a p-GaN contact layer 33 are formed in this order on the p-AlGaN cladding layer 29 and the n-AlGaN current blocking layer 31. A partial region from the p-GaN contact layer 33 to the n-GaN layer 25

is removed by etching. A p electrode 34 is formed on the p-GaN contact layer 33, and an n electrode 35 is formed on the exposed surface of the n-GaN layer 25.

In the semiconductor laser device shown in Fig. 13, a GaN based semiconductor layer 36 from the n-GaN layer 25 to the p-GaN contact layer 33 is formed on the GaN layer 24 having no dislocations. Accordingly, few dislocations exist in the GaN based semiconductor layer 36. Consequently, a semiconductor laser device capable of a low-current operation and a low-voltage operation is obtained.

Although in the present embodiment, description was made of a case where the method of forming the nitride based semiconductor layer according to the present invention is applied to the semiconductor laser device, the method of forming the nitride based semiconductor layer according to the present invention is also applicable to light emitting semiconductor devices such as a light emitting diode and the other semiconductor devices.

Although in the example shown in Figs. 9 and 10, the GaN layer 23 is etched such that it remains on the bottom surfaces of the recesses in forming the striped irregular pattern on the surface of the GaN layer 23, the GaN layer 23 may be etched until the sapphire substrate 21 is exposed to the bottom surfaces of the recesses, as shown in Figs. 14 and 15, in forming the irregular pattern on the surface of the

GaN layer 23.

As shown in Figs. 14 (a) and 14 (b), an AlGaN buffer layer 22 and an undoped GaN layer 23 are successively grown on a (0001) plane of a sapphire substrate 21, as in Figs. 19
5 (a) and 19 (b). The thickness of the GaN layer 23 is approximately 0.5 μm to 5 μm, for example. Also in this case, dislocations 37 extending in the vertical direction exist in the GaN layer 23.

An SiO$_2$ film is then formed on the entire surface of the
10 GaN layer 23, and striped masks composed of photoresist are formed on the SiO$_2$ film. The SiO$_2$ film is etched using a hydrofluoric acid, to form striped SiO$_2$ films 30, as shown in Figs. 14 (c).

Thereafter, as shown in Fig. 14 (d), the GaN layer 23
15 and the AlGaN buffer layer 22 are etched until the sapphire substrate 21 is exposed using the SiO$_2$ films 30 as masks and by RIE using chlorine gas, to form a striped irregular pattern on the surface of the GaN layer 23. The respective widths D of a recess and a projection in the irregular pattern shall
20 be 5 μm, for example.

Thereafter, as shown in Fig. 15 (e), the GaN layer 24 is regrown. At this time, the underlying GaN layer 23 is exposed only to the side surfaces of the irregular pattern. When the regrowth of the GaN layer 24 is started, therefore,
25 the GaN layer 24 is not grown in the vertical direction and

is grown only in the lateral direction. No dislocations exist in the GaN layer 24 which is grown in the lateral direction on the sapphire substrate 21.

As shown in Fig. 15 (f), as the GaN layer 24 is regrown,
5   the recesses in the irregular pattern are filled in with the GaN layer 24. The GaN layer 24 is grown in the vertical direction.

Thereafter, as shown in Fig. 15 (g), the GaN layer 24 is grown in the lateral direction as well as the vertical
10 direction on the SiO_2 films 30 on the top surfaces of the projections in the irregular pattern. Accordingly, the surface of the GaN layer 24 is flattened. Consequently, the GaN layer 24 of high quality having no dislocations is formed on the SiO_2 films 30 on the irregular pattern and the sapphire
15 substrate 21.

As in the example shown in Fig. 9 and 10, in order to flatten the surface of the GaN layer 24 which is regrown, the GaN layer 24 must have a certain degree of thickness. The thickness required to flatten the surface of the GaN layer
20 24 differs depending on the growth conditions such as the width of the irregular pattern on the underlying GaN layer 23 and the substrate temperature at the time of the growth of the GaN layer 24. For example, when the respective widths of the recess and the projection in the irregular pattern are
25 5 μm, the thickness of the GaN layer 24 must be approximately

10 to 20 μm.

GaN is easily grown in a $\langle1\bar{1}00\rangle$ direction. In order that the GaN layer 24 is easily grown in the lateral direction in the steps shown in Figs. 15 (e), 15 (f), and 15 (g), 5 therefore, it is desirable that the striped SiO_2 films 30 are formed in a $\langle11\bar{2}0\rangle$ direction perpendicular to the $\langle1\bar{1}00\rangle$ direction of the GaN layer 23 in the step shown in Fig. 4 (c).

Furthermore, in order that the surface of the GaN layer 24 which is regrown in the step shown in Fig. 15 (g) is easily 10 flattened, the width of each of the striped SiO_2 films 30 formed in the step shown in Fig. 14 (c) and the window width of the striped SiO_2 films 30 (the width of a region where the SiO_2 films do not exist) are preferably as small as not more than 10 μm, and more preferably not more than 1 to 5 μm.

15 It is preferable that a cross-sectional shape of the projection in the irregular pattern on the GaN layer 23 is a rectangular shape or a reversed mesa shape having vertical side surfaces rather than a mesa shape, as in the example shown in Figs. 9 and 10.

20 Although in the example shown in Fig. 14 and 15, the sapphire substrate 21 is used as an insulating substrate, the sapphire substrate 21 may be also replaced with another insulating substrate such as a spinel substrate.

Figs. 16 and 17 are schematic sectional views showing 25 the steps of a method of fabricating a semiconductor laser

device in a third embodiment of the present invention.

As shown in Fig. 16 (a), an AlGaN buffer layer 42 having a thickness of 30 Å, an undoped GaN layer 43 having a thickness of 2 μm, and an Si doped n-GaN layer 44a having a thickness

5 of 3 μm are grown in this order on a (0001) plane of a sapphire substrate 41.

As shown in Fig. 16 (b), an SiO_2 film having a thickness of approximately 1000 Å is then formed on the n-GaN layer 44a. The SiO_2 film in a region excluding a light emitting portion

10 is then removed by etching, and the SiO_2 film in a region corresponding to the light emitting portion is patterned in a stripe shape, to form a plurality of striped SiO_2 films 45. In this case, the striped SiO_2 films 45 are formed in a <1 120> direction of the n-GaN layer 44a such that GaN is easily

15 grown in the lateral direction in the subsequent step.

The width of each of the striped SiO_2 films 45 is approximately 0.5 μm, and a pitch between the striped SiO_2 films 45 is approximately 1 μm. In order to realize fundamental transverse mode lasing, the width W1 of the light

20 emitting portion is preferably about 2 to 5 μm, and the number of the striped SiO_2 films 45 must be approximately 3 to 5.

Thereafter, as shown in Fig. 16 (c), an Si doped n-GaN layer 44b having a thickness of 5 μm, an Si doped n-InGaN crack preventing layer 46 having a thickness of 0.1 μ

25 m, and an Si doped n-AlGaN cladding layer 47 having a

thickness of 1 μm are grown in this order on the n-GaN layer
44a. Further, an MQW active layer 48 having the structure
shown in Fig. 7, an Mg doped p-AlGaN cladding layer 49 having
a thickness of 1 μm, and an Mg doped p-GaN contact layer 50
5   having a thickness of 0.1 μm are grown in this order on the
n-AlGaN cladding layer 47.

In this case, in a region where the striped SiO_2 films
45 exist, GaN is grown in the vertical direction from the
underlying n-GaN layer 44a between the striped SiO_2 films 45,
10 and GaN is then grown in the lateral direction on the striped
SiO_2 films 45. On the other hand, in a region where the striped
SiO_2 films 45 do not exist, GaN is grown in the vertical
direction from the underlying n-GaN layer 44a. Consequently,
a difference substantially arises in the growth rate of GaN
15 between the region where the striped SiO_2 films 45 exist and
the region where the striped SiO_2 films 45 do not exist. That
is, in the region where the striped SiO_2 films 45 exist, the
growth rate of GaN is substantially lower, as compared with
that in the region where the striped SiO_2 films 45 do not
20 exist. The difference in the growth rate is continued until
the striped SiO_2 films 45 are completely filled in with GaN
so that the growth in the lateral direction is completed.

As a result, the surface of the n-GaN layer 44b is
concavely formed. Further, the n-InGaN crack preventing
25 layer 46, the n-AlGaN cladding layer 47, the MQW active layer

48, the p-AlGaN cladding layer 49, and the p-GaN contact layer 50 are concavely formed. A concave part of the MQW active layer 48 is a light emitting portion which is an active region of the device. Further, few crystal defects exist in a GaN

5   based semiconductor layer 56 on the region where the striped SiO$_2$ films 45 exist.

Thereafter, as shown in Fig. 17 (d), a partial region from the p-GaN contact layer 50 to the n-GaN layer 44b is removed by etching, to expose the n-GaN layer 44a.

10   Furthermore, as shown in Fig. 17 (e), an SiO$_2$ film 51 is formed on the top surface and side surfaces of the p-GaN contact layer 50 and the top surface of the n-GaN layer 44a in order to narrow a current and protect an exposed portion of a pn junction except in a region above the light emitting

15   portion and an electrode forming region of the n-GaN layer 44a.

Finally, as shown in Fig. 17 (f), a p electrode 52 is formed on the exposed surface of the p-GaN contact layer 50, and an n electrode 53 is formed on the exposed surface of the

20   n-GaN layer 44a.

In order that a current is not uselessly injected into the light emitting portion, it is preferable that the window width W2 of the SiO$_2$ film 51 to be a current injection region is made equal to or slightly smaller than the width W1 of the

25   light emitting portion.

In a method of fabricating the semiconductor laser device according to the present embodiment, the crystallizability of a GaN based semiconductor layer 56 on the region where the striped SiO_2 films 45 exist, and the MQW

5 active layer 48 in the light emitting portion is concavely formed by a difference in the growth rate which arises during the growth in the lateral direction of GaN.

Consequently, a difference in the index of refraction appears in not only the vertical direction but also the

10 horizontal direction of the sapphire substrate 41. As a result, it is possible to easily fabricate a refractive index guided structure by performing crystal growth twice without carrying out the etching step. Consequently, a refractive index guided semiconductor laser device which is uniform in

15 device characteristics and is high in reproducibility is realized.

Although in the present embodiment, description was made of a case where the present invention is applied to the semiconductor laser device, the present invention is also

20 applicable to light emitting semiconductor devices such as a light emitting diode and the other semiconductor devices.

Although in the third embodiment, description was made of the semiconductor laser device using the sapphire substrate 41, it is possible to use substrates such as an SiC

25 substrate and a spinel ($MgAl_2O_4$) substrate in place of the

sapphire substrate 41.

Although in the above-mentioned first, second and third embodiments, the SiO$_2$ films 4, 30, and 45 are used as insulating films for carrying out epitaxial lateral

5   overgrowth, the SiO$_2$ film may be replaced with other insulating films such as an Al$_2$O$_3$ film and a TiO$_2$ film.

Although in the above-mentioned first, second and third embodiments, the nitride based semiconductor layer contains Ga, Al, and In, the nitride based semiconductor layer may

10   contain boron (B).

Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the

15   present invention being limited only by the terms of the appended claims.